NEXT MEETING, MARCH, 25, 1904.
Subject: HIGH-TENSION TRANSMISSION. Papers to be discussed are printed in this issue of the Transactions. See pages 1-18.

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TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

ELECTRICAL ENGINEERS.

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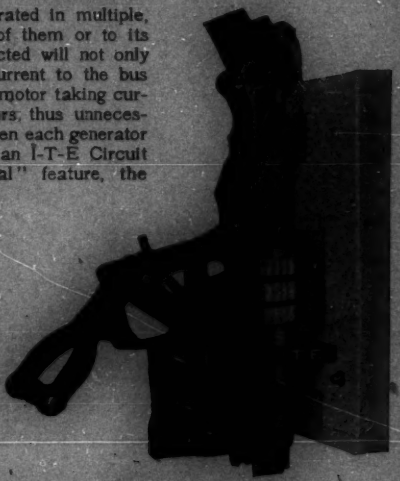

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EXPLANATION.

The following papers are "Introductions" to a discussion to take place at the INSTITUTE meeting at New York, March 25, 1904. They are not intended to be formal or complete "Papers" but serve merely as a basis or framework for discussion on the subjects with which they deal. All those connected with the INSTITUTE and desiring to take part in this discussion may do so by being present at the meeting or if this is not possible by sending in a written "Contribution."

In contributing to a discussion, whether verbally or in writing, it is requested that the matter under discussion be taken up under the several heads and in the order made use of in the Introduction, and that following the treatment of these heads there be introduced any other matter which the Contributor may deem advisable. When the Contributions are made by mail on more than one of the topics under consideration at the same meeting, it is requested that the several Contributions be embodied in separate letters.

Contributions will be read at the meeting for which they are intended either in full, in abstract, or as part of a general statement giving a summary of views of those taking the same position in the matter under discussion.

It should be borne in mind that the Introductions are written in order to provoke discussion and that there should be no hesitancy in attacking them if they do not agree with the opinions of the Contributor. On the other hand, if the Contributor agrees with the matter of the Introductions, either as a whole or in part, he should state the fact.

It should also be borne in mind that the principal object of this scheme is to enable and encourage those not in a position to attend meetings to take part in the discussion. If one does not feel himself qualified to discuss certain portions of an Introduction, but is able to discuss other parts, it is to be hoped he will contribute to the latter.

Contributions to the discussion of these papers should be mailed to Ralph D. Mershon, 29 Broadway, New York, so that they will be received not later than March 19th, 1904.

A paper to be presented at the 185th Meeting of the American Institute of Electrical Engineers, New York, March 25, 1904.
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THE RELATIVE FIRE-RISK OF OIL AND AIR-BLAST TRANSFORMERS.

BY E. W. RICE, JR.

Two types of transformers have been extensively used in electrical installations up to date, distinguished by the method of insulation and cooling employed. The "oil transformer" relies upon oil as the cooling and insulating fluid. The "air-blast transformer" contains insulation material mainly of cloth, paper, and wood impregnated with oil or varnish, and is cooled by the circulation of a blast of air. In both types the insulating material is of an inflammable nature and under certain abnormal conditions may take fire with more or less serious consequences.

The electrical engineer must, therefore, consider carefully not only the relative but the actual fire-hazard which exists, and by proper and common sense methods minimize such danger. Both types can be made entirely safe by correct methods of design and installation.

I think it will be admitted that in general that type which contains the greater quantity of inflammable material will occasion the greater fire-hazard. The inflammable material in an air-blast transformer of say 1 000-kw. capacity will amount to about 800 lbs. in an oil-cooled transformer of the same capacity the amount will be about 7300 lbs. While this comparison cannot be taken as a measure of the relative fire-risk, it is an indication to be considered, especially in view of the fluidity, the low temperature of ignition, and high calorific value of oil.

While the quantity of inflammable material in an air-blast transformer is, as stated, relatively small, it has an extended surface exposed to a large volume of air, and therefore, if a fire

starts from internal causes, such as short-circuit or extreme overload, is capable of rapid combustion. This combustion could be checked by shutting off the flow of air to a transformer by means of a diaphragm automatically closed by the melting of a fusible link, the fusible link so located as to be melted by the first contact with flame; a method similar to that employed for closing fire doors in buildings.

An oil-transformer properly cooled is probably not particularly subject to ignition of the oil from internal burn-outs or arcs. It is well-known that oil is an excellent medium for the smothering of alternating arcs, and this principle is utilized in connection with oil-switches.

The vapor above the oil, may however, be ignited by electrical discharges. Even in this case, while the quantity of combustible material is enormous, the surface exposed is relatively small. The principle fire-hazard in an oil transformer is due to the large mass of inflammable liquid material which under certain conditions may become totally consumed. It becomes a special hazard in the case of fire from sources external to itself.

Considerations of first cost, economy of space, simplicity, operating costs, etc., have resulted in placing transformers in the same room with switchboards and other apparatus, such as synchronous converters, motor-generators, etc. Under such conditions, it would seem that the air-blast transformer constituted the lesser fire-risk than the oil transformer, and would therefore be generally employed if the fire-risk were the only consideration. The air-blast type, however, is limited in practice to pressures of about 30 000 to 35 000, as the static discharge which occurs at much higher pressures would in time break down the insulation. It is therefore necessary to employ oil insulation on the higher pressures now common.

The fire-risk can be practically eliminated by placing such transformers in a room or rooms separated by suitable fire walls from the other part of the plant. This plan has already been proposed and introduced. An entirely separate building, subdivided again into suitable rooms, may be employed where the maximum of safety is demanded. Much may be done to limit the risk, even when the transformers are placed in the same room with other apparatus, by proper systems of piping for drainage of the oil away from the building, by placing the transformers in a depressed area of concrete arranged for rapid drainage, etc. Of course any of the methods commonly employed for preventing,

limiting, or extinguishing oil fires may properly be employed.

In closing I wish to state that I consider a discussion of this subject both timely and important. It is well for engineers to consider carefully the dangers of all kinds, both to life and to property, that may exist in connection with the use of electrical appliances. The art is not advanced by ignoring or belittling the existence of real difficulties, but rather by intelligently facing the problems which occur and seeking a proper solution. Electrical energy is capable of being produced, handled, and transmitted more safely than any other form of energy, and such dangers as exist usually can be foreseen and safe remedies can be applied. On the other hand, we must not exaggerate the danger of fire from the use of transformers of either the oil or air-blast type. I believe the fire-hazard is extremely small, and can be and is being reduced to a negligible quantity by the adoption of methods similar to those I have outlined here.

A paper to be presented at the 185th Meeting of the American Institute of Electrical Engineers, New York, March 25th, 1904.
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THE USE OF GROUP-SWITCHES IN LARGE POWER-PLANTS.

BY L. B. STILLWELL.

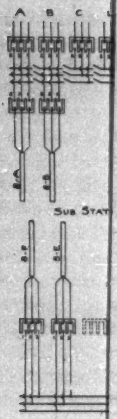
In a number of large electric generating plants recently designed in America, the feeder circuits are divided into a plurality of groups, and a switch designated a "group-switch" is connected into the circuit between the main bus-bars and each group of feeders. Obviously, no switch should be added to an organization of switch gear already very complicated and expensive, unless its practical usefulness fully justifies its adoption. As this subject has never been discussed by the INSTITUTE, the writer avails himself of the opportunity presented by the invitation of the Chairman of your Transimssion Committee to introduce it.

In considering a subject such as this, accurate generalization is difficult if not impossible. Probably no one who knows what engineering means would affirm without qualification either that he approves the use of group-switches or that he does not approve their use. There are few hard and fast rules in engineering. If such matters as the use or non-use of group-switches could be settled once for all, and for all plants regardless of size, function, or attendant conditions, the purchasing agent would soon succeed the engineer, the pharmacist would take the place of the physician, and the capitalist investing his money in electric power development and use would have no occasion to seek among technical advisers for sound judgment resting upon broad experience and exercised in full knowledge of the existing state of the art, as well as recognition of its general direction and

tendency. Instead of attempting a generalization, therefore, we may consider more profitably the arguments for and against the group-switch in the case of a typical plant, and then glance at some of the modifications of function and circumstance, which in the case of other plants would affect our conclusions. The group-switch first appeared in the plant of the New York Street Railway Company at 96th Street, but as the writer had nothing whatever to do with the design of that plant, he selects for consideration the plant of the Manhattan Railway Company. In this plant two complete sets of main bus-bars are used. Switches are provided by means of which each of these sets may be divided into two independent sets of bus-bars to each of which four alternators and four groups of feeders may be connected. Eight group-switches are provided, through each of which current is supplied to a set of auxiliary bus-bars, to which in turn the individual feeders are connected through their respective switches. One of the eight feeder-groups is used to supply power to auxiliaries in the power-house. The other seven groups supply power, respectively, to the seven sub-stations which receive power from this central source. All switches in the high-pressure alternating-current circuits are of the motor-operated oil type.

The arguments in favor of the group-switch as used in the plant of the Manhattan Railway Company are: 1—it affords an additional means of opening a feeder-switch that fails to open its circuit, when operated for that purpose. The advantages of the group-switch in respect to this function to-day appear materially less than they did five years ago, for the reason that the power-operated oil-switch within the period named has demonstrated a high degree of reliability. However, it cannot be assumed that the feeder-switch is invariably reliable, and, therefore, judgment of the weight of the argument in favor of the group-switch, based upon its use as a reserve for the feeder-switch, becomes a question of judgment of the chances of failure of the feeder-switch on the one hand and the seriousness of total interruption of power supply on the other.

2—It affords means of reducing aggregate load upon the power-house in case of necessity, more rapidly and otherwise less objectionably than the usual method of cutting off individual feeders. It will sometimes happen in the operation of a power-plant that it becomes necessary suddenly to shut down one of the generating units. If the load carried at the time be such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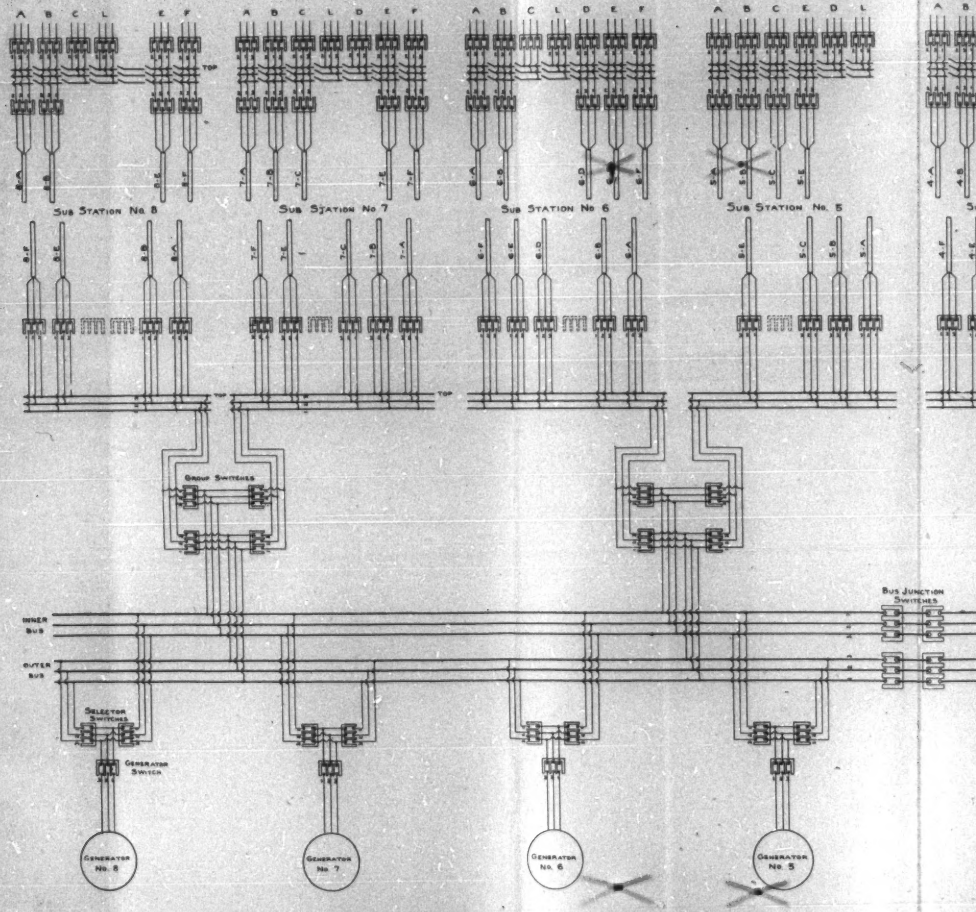

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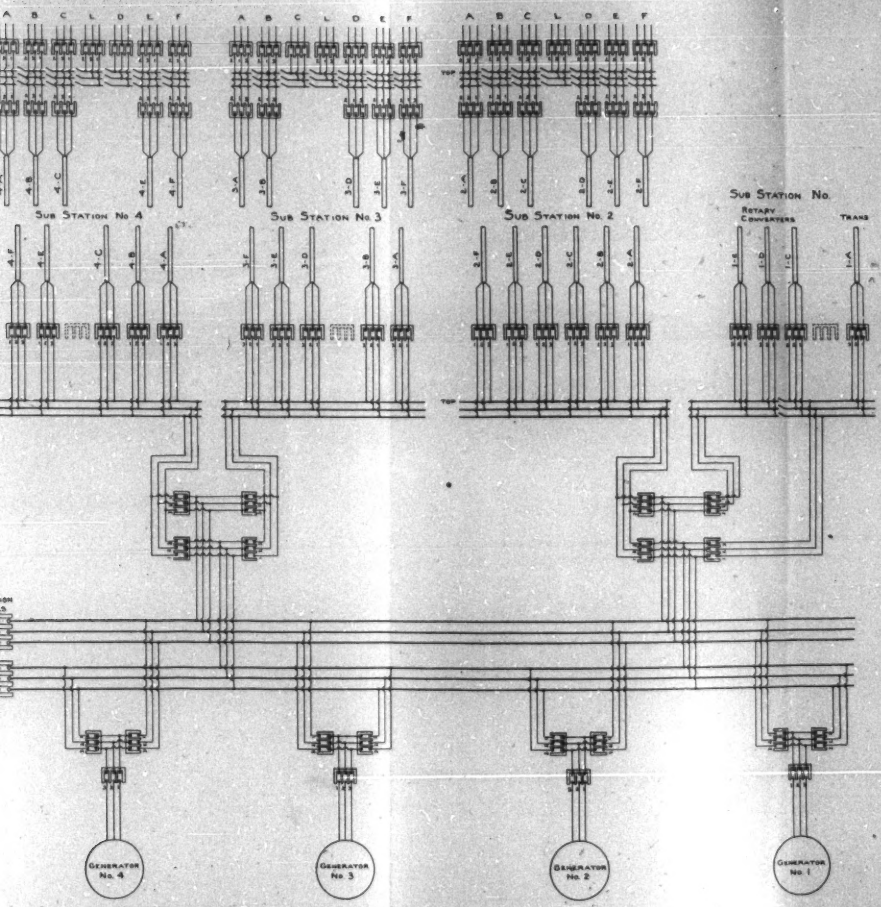

Manhattan Railway Co.
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New York

that the shutting down of the generator implies reduction of the external load, this can be accomplished most conveniently by operating one or two group-switches.

3—Where duplicate main bus-bars are used it facilitates transfer of load from one set to the other, in case it becomes necessary suddenly in operation to make such transfer. As bus-bars and connections are now installed in our best plants, this necessity does not arise frequently; nevertheless it is liable to occur, and obviously half a dozen group-switches may be used to affect the transfer in much less time than would be required were five or six times that number of individual feeder-switches used.

4—The grouping of the external feeder-circuits in group units bearing a simple fixed relation to the generator units establishes a symmetry and proportion most useful to the operator, particularly in times of emergency. In the case of the plant under consideration, at times of full load, the power passing through each group-switch is substantially equal to the output of one generating unit. This relation of course does not exist under partial loads, but under such loads it is not difficult usually to keep in service generating capacity exceeding the load by a margin sufficient to make it possible to shut down one generator without cutting off feeders; and in cases where this margin of capacity is not kept in service it is, nevertheless, a more speedy and certain operation to cut off the necessary number of groups of feeders than it would be to cut off a proportionate number of individual feeders.

The arguments against the group-switch are: 1—It introduces additional apparatus and, therefore, in itself increases the risk of interruption due to failure in switch insulation, etc. The successful operation of many plants, particularly in America, has been interfered with by the introduction of too much switch gear and too many safety devices, automatic and other; these additions in themselves being responsible in some cases for more trouble than they prevent; and it is to be noted that the group-switch implies the auxiliary bus-bar. Here again it is impossible to dogmatize, for as the result of additional experience, the judgment of to-day may be reversed five years from now. As an expression of personal opinion, however, I may say that if the group-switch and the auxilairy bus-bars be reasonably well insulated and installed, the interruptions originating in this additional apparatus should be almost negligible in the case of such a plant as that which we are considering.

2—The group-switch and its bus-bars imply, of course, an increase of cost of the plant. In case of the Manhattan plant this increase is about 10 per cent of the cost of the switch gear and measuring apparatus, and about four-tenths of one per cent of the cost of the plant. To put it another way, the cost of the group-switches and bus-bars for the plant approximates $20 000, and the annual cost, assuming this to be 10 per cent of the investment cost, is $2000, which is about two-tenths of one per cent of the annual cost of operating the entire plant, including substations.

In the plants in which the feeder unit equals or exceeds the dynamo unit of power, the group-switch, of course, disappears. In this case, however, it may still be advisable to use two feeder-switches in series in order to avoid the necessity of shutting down the entire plant in case of the failure of a single feeder-switch.

Obviously, also, there is no reason for attempting to use group-switches in cases where the total number of feeders is small.

For plants comparable in magnitude to the plant of the Manhattan Railway Company, using a very considerable number of feeders, the group-switch is important and its use generally advisable.

A paper to be presented at the 185th Meeting of the American Institute of Electrical Engineers New York, March 25, 1904.
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OIL-SWITCHES FOR HIGH PRESSURES.

BY E. M. HEWLETT.

This paper naturally compares the oil-break switch with the air-break switch. In treating this subject the following points appear to be the main points for consideration:

1—Abnormal Rise in Pressure: owing to the fact that in oil-switches the circuit is opened at the zero point of the wave, the rise of pressure found in the air-break switch is not experienced. This point is of particular importance in high-pressure, long-distance lines, and in cables carrying considerable energy.

2—Capacity: experience has proved that oil-switches may be designed to break circuits of practically unlimited capacity.

3—Length of Arc: owing to the smothering action of the oil on the arc the length of arc under oil is only a fraction of its length in air.

4—Insulation: the insulating qualities of the oil decrease the distance required to prevent leakage and arcing.

5—Size of Switch: owing to the fact that the arc length is materially decreased and the value of the oil as an insulation reduces the creeping surface, an oil-switch can be made very much more compact than an air-switch.

6—Remote Control: the design of the oil-switch lends itself readily to operation by control from a distance.

7—Arc Confined: the fact that the arc is ruptured under the oil within the switch has two advantages; 1st. switches can be placed close together without danger of short-circuit; 2d. in case of emergency, confusion is avoided as there is no visible arc to disconcert the attendant.

8—Station Arrangement: the flexibility of the oil-switch places no limitations on the station arrangement, permitting the circuits and busses to be arranged in the most advantageous manner.

9—Isolation of Phases: the possibility of complete isolation of the phases in a reasonable space is easily secured by the use of oil-switches.

A paper to be presented at the 185th Meeting of the American Institute of Electrical Engineers, New York, March 25th, 1904.
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TERMINALS AND BUSHINGS FOR HIGH-PRESSURE TRANSFORMERS.

BY WALTER S. MOODY.

This subject will include cables, straps, connectors, etc., for both high- and low-tension side, designed both for terminal connections and for changes in the ratio of transformation, together with their insulation. In transformers for moderate pressure and having but two high- and low-pressure terminals, the problem of terminals is a simple one; with higher pressures and numerous changes in the ratio, however, the design of these parts of the transformer often become a most difficult problem upon the proper solution of which depends, to no small extent, the reliability of the transformer.

Location of Terminals on Coils.

It is much better to have the high- and low-pressure terminals at opposite ends of the structure, for it is almost impossible to keep safe distances between the terminal and connecting coil leads, when all are at one end. In a shell-type structure, having its coils in vertical position, this requires one set of coil terminals to be at the bottom of the case, but to bring these safely to the top is not as difficult as to separate high and low-pressure conductors that are at the same end of the windings.

Insulation of Terminals on Coils.

In an oil-immersed transformer, this presents little difficulty, as it is simply necessary to have all leads rigidly spaced a safe distance from each other and from the coils, and covered with sufficient waterproof insulation to prevent any moisture penetrating the coil around the terminals before the oil is put in.

In air-blast transformers, however, the case is different; here all terminals must be covered with an insulation integral with that on the coil itself, to a distance from the coil that provides sufficient surface insulation, even when the lead is well covered with dust and dirt.

Often the dielectric strength of a transformer is materially lowered by allowing the coil-terminals or taps to project beyond the sides of the coils, thus shortening the distance between the primary and secondary. "Spreading" the exposed ends of the windings removes this difficulty, except when the terminal comes from a point well within the coil, but introduces a more serious defect, lack of rigidity to withstand the strains of short-circuits. Usually the problem can be solved by so winding coils as to have only outside terminals and locating such coils as have taps on the outside of the coil structure.

Location of Main Terminals.

The best location for these naturally varies with the type of transformer and its pressure; for the air-blast type, the air-chamber forms a convenient and natural location for the low-pressure wiring, and the terminals of these are therefore usually located in the base of such transformers and made accessible by doors in the side of the base. For pressures not exceeding 25 000 volts, the high-pressure wiring can also be placed in the air-chamber, without making the air-chamber of excessive cross-section, so that all transformer terminals are in the base and exposed wiring is avoided. Heavy rubber-insulated cable is to be avoided in such construction, however, for should the rubber take fire from short-circuit or other causes a draft of air will carry the fire along the duct and into the transformers with great rapidity.

In oil-filled transformers the terminals are, of necessity, located at or near the top of the case. Often for convenience in extern wiring, projecting pockets are provided through which terminal-leads may leave the case in a downward direction. With such construction, it is necessary to have a solid section in the cable, just above the oil line, and to have this section uninsulated or covered with an insulation impervious to oil, otherwise the cable and insulation will act as a siphon and discharge oil.

Insulation of Main High-Pressure Terminals.

Below 40 000 volts, the insulation of terminals offers no special difficulty; porcelain or glass bushings can readily be obtained that are safe for this pressure, even if the conductor

has no insulating covering. For higher pressures, the problem is more difficult, if no insulation is used on conductor, the bushings become expensive and so large that there is scarcely room on top of a moderate size transformer for as many terminals as are often required. The following are some of the more common forms of bushings that have been used:

Wooden tubes;

Hard-rubber tubes;

Glass and porcelain tubes, both single and concentric;

Numerous forms of molded porcelain bushings.

Wooden tubes of the necessary size cannot be thoroughly dried and filled. Hard rubber is so apt to contain impurities that it is unsatisfactory; moreover, it deteriorates rapidly if ozone is generated near it. Glass is fragile and must be protected with other semi-insulators. Porcelain, or any smooth tube, must be very long if it have sufficient leakage surface to be safe when dirty, and even the best shapes of corrugated bushings are large and expensive when capable of withstanding a test of from 75 000 to 160 000 volts.

All things considered, the writer has found the following practice, quite satisfactory for test-pressures not exceeding 160 000.

Insulate the lead with varnished wrappings that will safely withstand for one minute about half of the test pressure to be applied, bringing out this lead through a porcelain bushing having the same strength as the insulation of the lead, and sufficient surface to prevent leakage at this pressure when dirty; in other words, let the insulation of the leads be sufficient for the working pressure, and the porcelain be of such strength as to give the factor of safety desired. This combination forms a far safer insulation than a bare conductor and a larger bushing which would stand the same puncture test as the combination, from the well-known fact that oxidized linseed oil is an insulation that will momentarily stand several times as much as it will for any considerable length of time, while porcelain, glass, etc., have no such time-factor.

In leads requiring a test of 100 000 volts or more, and insulated in this manner, an additional difficulty is met in the induced charge on the outer surface of the insulation; at this pressure the surface is covered with a heavy brush discharge that so reduces the surface resistance to leakage that 100 000 volts will travel along several feet. It is usually impracticable to make the insulated lead long enough to withstand the pressure under

these conditions, but the discharge may be broken up, so that it will not appreciably reduce the surface resistance, by bell-shaped pieces of rubber, porcelain or other insulation slipped over the lead before all the varnished wrappings are put on, and having its small end so shaped as to allow of its being burned in the outer wrappings.

In transformers designed for Y-connection and grounded neutral, some transformer builders, in order to save expense on high-pressure bushings, have grounded one terminal on the case and insulated only; such leads as are to be connected to the line; this prevents operation with Δ connections, but otherwise seems unobjectionable. In similar manner, the use of three-phase transformers with the inter-connecting between the phases made within the case reduces the expense and possibility of trouble with bushings.

Eighty thousand volts is the highest pressure that is now practicable for transmission work, but transformers and insulators must be tested, consequently there is some demand for transformers working up to 200 000 volts. The insulation of the terminals of such transformers is the most formidable part of their design. As yet, I know of no satisfactory solution of the problem except to use oil-filled tubes as terminals. A terminal that has withstood 375 000 volts without any indication of weakness is constructed as follows:

The tube was the shape of two truncated cones, bases together; about 12 inches in diameter at the centre, and four inches at either end; it was built up of thin wooden rings, telescoped a short distance into each other, and held together by the conductor, which, for mechanical purposes was made quite heavy, and which was located in the axis of the cones and supported by washers at either end of the tube; between each section of the tube were collars of insulating material, some three inches larger in diameter, than the tube which served the purpose of greatly increasing the leakage surface. After the sections were drawn tightly together by nuts at each end of the conductor, the whole structure was repeatedly dipped in varnish and dried, thus sealing all joints. The terminal was mounted with the lower end several inches under the oil in the transformer and with its largest diameter on a level with the cover; the lower end of the tube was tightly sealed, making the tube perfectly oil-tight.

Internal Terminals.

At present we are passing through a period of development in

line construction. Each engineer of a new transmission system of considerable length desires to use as high pressure as possible with a line construction of reasonable cost, but few are sure whether 50, 60, 70 or 80 thousand volts is the safe maximum for their conditions. It is common, therefore, for the manufacturers to be asked to make transformers that can be operated at several voltages on the high-pressure side. The result, whether accomplished with series-multiple connection, changing from Δ to Y, or simply by taps, usually requires so many terminals, that it becomes quite impracticable to place all the necessary leads outside of the case, even were it desirable to do so; consequently, accessible terminals inside the case must be provided. Again, at these and lower pressures, also, it is usually desirable to provide for limited range of adjustment in the ratio, say by 2 percent, with a total of 10 percent; such changes are usually too small to be made except by means of taps on the high-pressure windings. Except in transformers of very large capacity, there would be no room safely to insulate so numerous terminals above the surface of the oil; the practice is therefore to locate such terminals just under the oil and make them as accessible as possible, either by the removal of the transformer top, or through an auxiliary cover on the top of the case. It is better that each of these terminals be separately supported by glass or porcelain insulators, for a single support, such as a slab of marble, is almost sure to collect sufficient semi-conducting material to cause trouble sooner or later. Such terminals being, at the best, rather inaccessible there is danger that a wrong or imperfect connection will be made when changes are desired; the following method of mounting transformers in the tank greatly simplifies the problem of getting at such terminals, especially when transformers are installed under a crane; Instead of supporting the transformer proper on the base of the case as usual, it is hung from a strong cover; the interior terminals are placed in about the usual position, but are supported by the bolts carrying the transformer. To get at these terminals it is then simply necessary to raise the cover with the transformer, until the terminals are on a level with top of case; connections may then be made with convenience and safety and the transformer returned to its position in the tank.

Low-Pressure Terminals.

Usually these present no special difficulties; when transformers are connected in multiple and deliver 500 amperes or

more, special caution should be taken that all joints are soldered or that terminals are of such construction as to have extremely low contact resistances. Taper plugs and receptacles are perhaps the most reliable form of contact for the purpose.

Current in excess of 500 amperes should never be brought out through separate openings in the case, otherwise there will be local heating around the terminal and needless reactance introduced into the circuit. Currents over 2 500 amperes should be brought out by means of intermixed bus-bars for the same reason.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK, DECEMBER 18, 1903.

The 182d meeting was held this date at Carnegie Hall, 154 West Fifty-seventh Street.

SECRETARY POPE:—At a meeting of the Board of Directors this afternoon the following Associates were elected;

Name.	Residence.	Endorsers.
BERNAYS, CHARLES EDWIN,	Overland Representative, Noyes Bros., 45 Adelaide St., Queensland.	F. A. McCart. John Hesketh. W. G. T. Goodman.
BINGAY, ROBERT V.,	Pittsburg Transformer Co., Pittsburg, Pa.	V. G. Converse. E. F. Price. F. W. Roller.
BOERI, ALBERI P.,	Chief Inspector, Engineering Dept., The N. Y. and N. J. Telephone Co., 81 Willoughby St., Brooklyn, N. Y.	B. Gherardi, Jr. Hobart Mason. R. M. Ferris, Jr.
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CARR, JOHN HERBERT,	Chief Electrician, Arnold Print Works, North Adams, Mass.	G. H. Berg. A. F. Rolf. C. C. Chesney.
CARTER, THOMAS BAILEY,	Superviser of City Lighting. St. Louis, Mo.	Gerard Swope. F. R. Mott. G. F. Durant.
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FETHERLING, HERSCHEL GEORGE, Salesman and Engineer, Northern Electric Mfg. Co., 126 E. Dayton St., Madison, Wis.	J. P. Mallett. T. E. Drohan. F. V. T. Lee.
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HIROKAWA, TOMOKICHI, Chief Engineer, Kyoto Electric Light Co., Kyoto, Japan.	Zentaro Iijima. H. Maki. K. Iwadare.
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OVERHEAD HIGH-TENSION DISTRIBUTING SYSTEMS IN SUBURBAN DISTRICTS.

BY GEORGE H. LUKES.

The problem of building up and operating a satisfactory distributing system for the suburban towns and villages surrounding a large city presents many peculiar difficulties. The problem is more often to reconstruct an existing system, making use of as much of the old work as possible and at the same time making provision for future growth. Obstacles are usually encountered in the work. Many different interests have to be satisfied, and in some cases the engineer is compelled to use construction which is not desirable, but is necessary under the circumstances. It is seldom that the engineer is given the opportunity to lay out a complete system which can be operated economically and safely with a reasonably low first cost.

The villages surrounding a large manufacturing city are of several different types. The oldest ones are located on the lines of steam railways radiating from the city, and are residential in character. As transportation facilities are improved, new suburbs are started at greater distances from the city. The older ones become more thickly settled and even grow to be cities themselves. Some of the villages are made up of people of moderate means, whose houses are fairly close together. Others are built up by wealthy people who buy tracts of land and build large houses, which they occupy but four or five months in the year. Later on, the manufacturing suburb makes its appearance, consisting of a group of factories and a small business district surrounded by the houses of the workmen.

In the process of time, electric lighting plants are erected in

the larger villages and their pole lines are extended to the smaller villages near by to supply incandescent and street lamps. A large proportion of these small plants cannot be operated at a profit, and the result is a gradual deterioration in the stations and distributing systems, resulting finally in consolidations which bring large districts under the control of one company. It then becomes necessary to tie the various systems together, operating some of the stations as peak-plants and turning others into sub-stations, thus taking advantage of the fact that the peak may occur in the summer in one village and in winter in another.

Suburban business is so scattered that the cost of underground work is prohibitive and the distribution must be made by overhead wires. Public opinion is, however, intense in its opposition to overhead construction. The suburbanite objects to the multiplicity and unsightliness of the pole lines. He is in business in the city where the agitation against overhead wires has resulted in their being placed underground, and he refuses to believe that conditions are different in the country. In many communities local action has been taken compelling the use of joint lines by the electric light and telephone companies. These have been erected and operated successfully in many cases without any great danger. Joint lines should be avoided if possible, and it is important that every effort be made to make the pole lines unobtrusive. The poles should be well painted with a dull color, such as a dark olive-green, the wires kept taut and the connections made in a neat and symmetrical manner.

An overhead distributing system must be constructed so that the service will be reliable and not subject to frequent interruptions. The voltage regulation must be as good as possible, and danger to life and fire risk reduced to a minimum. This can be accomplished without adopting an extremely expensive method of construction. The great proportion of accidents and interruptions are caused by defects which are very easily guarded against, provided they are looked for. It is not the intention here to lay down rules for the construction of pole lines, but to draw attention to certain points which experience has shown to be often neglected.

Main Lines and Branch Circuits.—Main lines leading from stations should be on not less than 40-foot, and preferably on 45-foot poles. This gives plenty of room for additional circuits and makes it easier to cross above telephone and telegraph lines.

The branch circuits can be on shorter poles, but it is not advisable to use poles shorter than 30 feet. Where branch lines are taken off, the poles should be double-armed and buck-armed. Transformers, fuses, lightning-arresters and other devices should not be installed on main lines where it can be avoided.

Poles.—In the Middle West, the poles available at present are Michigan white cedar and Idaho cedar. Michigan poles are better proportioned than western poles and are longer lived. Michigan poles should have a top diameter of not less than seven inches. If western poles are used, eight or nine inch tops should be specified in order to obtain proper butt diameter. Michigan poles are sorted and sold under the specifications of the Northwestern Cedarman's Association and it is therefore cheaper to buy under the above specifications and sort out to suit. Poles should be shaved, roofed, and given one coat of paint in the yard. Poles are painted in order to improve their appearance, but the question of whether or not it adds to the life of the pole is an open one. In setting, particular care must be taken to select the best poles for the corners, turns, and ends of the line. If the line is on a highway that curves, set as many poles in a straight line as possible and make the turns on one or two poles, which can then be properly guyed. A line that changes its direction at every pole can never be held in position. Poles should be double-armed at corners, curves, and ends.

Guying.—This is one of the most important features in pole-line construction and is often neglected. Corners, junctions, and ends should be carefully guyed. Wherever the line changes in direction, even if the change is very slight, a guy should be placed. Patent guys and land-anchors should be used with great caution and only on light work. The best guy is the old-fashioned one consisting of a guy-stub, set at some distance from the pole with a galvanized iron anchor rod-bolted to a slug buried in the ground. Strain insulators should be inserted in the guy-wire and care be taken to make sure that the anchor-rod and guy-wire attached to it are grounded electrically.

Cross-arms.—The best cross-arms at present are made of southern yellow pine. They should be straight-grained, well-seasoned, free from knots, and purchased unpainted. They are the first part of the line to give out. The action of the sun's rays causes the arms to crack on top and they soon rot around the pin-holes. The usual method of treating is to paint them with white lead and oil, but in the West cross-arms boiled in carbol-

ineum have been used to some extent. The matter of the proper dimensions and pin-spacing for cross-arms has not received the attention it should, and it is high time that an attempt be made to standardize 4-, 6- and 8-pin arms for use on circuits up to 5,000 volts. The proper 6-pin arm for such use should have approximately the following dimensions: section, 3¼ inches by 4¼ inches; length, 8 feet; spacing, between pins about 16 inches, between pole-pin about 22 inches. Cross-arms for junction-holes should be of special size with greater distance between pins.

Insulators.—The ordinary deep-groove, double-petticoat insulator has proved satisfactory on 2,000-volt incandescent and 4,000-volt arc circuits. It is perhaps advisable to use triple-petticoat insulators on 4,000-volt polyphase work.

Fuse-blocks and lightning-arresters are sources of trouble on pole lines. In some instances systems have been operated entirely without fuse-blocks on the outside lines excepting, of course, the transformer blocks. The best plan is to install them on branch lines where there is a chance for trouble. Lightning-arresters should be installed to protect groups of transformers and branch lines. They should be frequently inspected and the ground-wires tested.

Transformers should be hung on double-arms below the lowest arm. If they are of large size the arms should be extra heavy and bolted securely to the pole. Methods of bringing the primary wires down from the circuit to the transformer are various and all are open to objections.

It is usually impossible to keep a regular arrangement of circuits upon cross-arms for the reason that as the business grows circuits of all kinds are added. It is very desirable, however, that circuits be kept in the same relative position throughout their length in order to facilitate tracing. Houses should be, as far as possible, grouped upon three-wire secondaries which should be carried alone on the lower arm. The installation of 200–400 volt, three-wire secondaries would facilitate this work wonderfully in scattered districts. The neutrals of three-wire secondaries should be grounded on the first pole away from the transformer.

All series alternating arc lamps should be provided with absolute cut-outs and high-voltage insulators in the lowering cable. Windlasses for raising and lowering lamps should be permanently grounded and an arc lamp when suspended from span-wires should be connected so that should it fall, the lamp will not fall toward the windlass but away from it.

The importance of frequent inspections of pole lines cannot be overestimated Old pole lines can be made very reliable, provided they are well guyed and weak points kept in repair. For inspection work, linemen of considerable experience are needed, because only long years spent in repair work gives the ability to predict where trouble is likely to occur.

Accidents caused by overhead wires are remarkably infrequent, considering the number of miles of pole lines operated. They occur most often to electric-light linemen, less often to telephone linemen and very rarely to citizens. Accidents to linemen can largely be prevented by employing on live work only steady and tried men, and using the inexperienced men and floating linemen on new construction work. Accidents to telephone linemen are mostly the result of want of care on the part of the men themselves. Accidents to citizens can be reduced to a minimum by care in constructing and maintaining lines.

The danger from fire is in the posibility of high-voltage current reaching buildings; first, through defective transformers, and secondly, through crosses between primaries and telephone wires. The first can be eliminated by grounding the secondary; the second can be made remote by proper coöperation between electric light and telephone companies in the erection of junction poles and substantial construction at crossings; the danger from fire is somewhat overestimated and it is to be sincerely hoped that any restrictive regulations will not only be carefully considered before final action is taken, but worked out in actual practice to determine whether or not their enforcement would introduce risks which would more than offset any advantage gained.

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AUTOMATIC APPARATUS FOR REGULAT NG GENERATOR AND FEEDER POTENTIALS.

BY E. J. BECHTEL.

Since the introduction of electricity as a source of illumination, one of the most important problems has been that of potential regulation; for the efficiency of the conversion of electricity into light depends greatly upon the maintenance of a constant potential at the lamp terminals. For instance, a system having a potential regulation of two per cent can profitably use incandescent lamps which consume 3.1 watts per mean horizontal candle-power, based on the oval-filament type of present quality, while a poorer regulation-factor would require the use of lamps consuming from 3.5 to 4 watts per candle-power, representing a sacrifice of from 12.5 to 30 per cent in conversion efficiency.

The potential of a shunt-wound generator drops very materially as the load increases. To overcome this drop, compound-winding of generators was introduced, being a step towards automatic potential regulation; but this only compensates for the inherent loss in the generator itself and is not capable of regulation for speed-losses nor for variations due to outside causes. Thus, if it is desired to maintain a constant potential at the switchboard or center of distribution under changes of any or all conditions, an external automatic potential regulator must be used.

There are a number of types of automatic generator potential regulators using different methods to accomplish the result. One type, the connections of which are shown in Fig. 1, has been in use in our station for the past four years on generators up to 250-kilowatt capacity operating under extreme conditions. This

regulator has given excellent service in alternating-current work, as will be seen by examining the curve on a section of recording-voltmeter chart shown in Fig. 2. This line was made by a 150-kilowatt, 60-cycle, alternating current generator, supplying current for the daylight incandescent load and operated from a jack-shaft driven by an engine which also operates a direct-connected 500-kilowatt, 500-volt, direct-current generator, supplying current for the street railway system. The larger part of the engine-load being very irregular, and the engine-governor not of the best, there are sudden fluctuations in speed, as shown by the

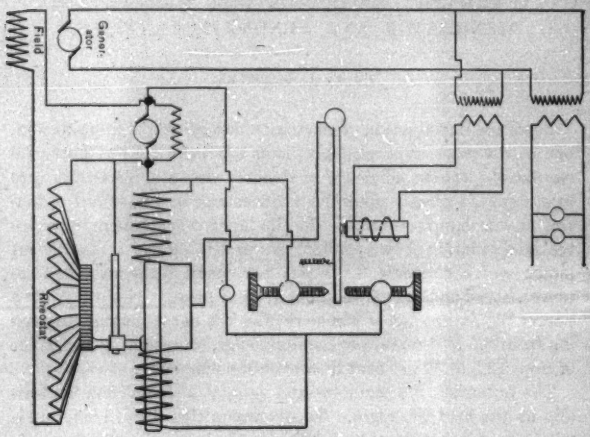

FIG. 1.

section of curve from a continuous speed recorder in Fig. 3. Each vertical section of the record has a value of 20 seconds, or three sections per minute. Each horizontal section has a value of three per cent in speed variation, or two cycles in the frequency of the generator. The variation of speed shown would not be advisable on inductive loads, but serves to show the efficiency of regulators under severe conditions.

This type of regulator, while very satisfactory as a generator potential regulator, and perhaps sufficient under favorable line and load conditions in small stations, does not correct the potential for variation in power-factor nor relative changes in the load on different feeders.

The system was adopted while our alternating load was comparatively small and operated from single-phase generators. With the intention of operating three-phase power circuits, we replaced the small single-phase generators with larger ones of three-phase 4,000-volt, four-wire type, the armature being star-connected with neutral connection brought out.

The 2,300-volt single-phase lighting circuits are connected to the different phases and neutral, balanced as nearly as possible between the different phases in regard to load conditions. Even with extreme care, a perfect balance cannot be maintained on

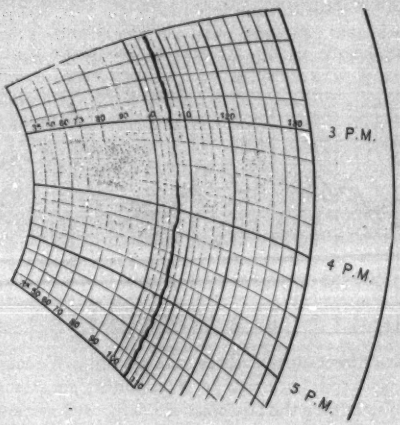

FIG. 2.

account of variations of load at different times on the individual circuits. To overcome this, we have ordered nine automatic feeder potential regulators of the boosting transformer type, having the secondary winding in series with the circuit and divided into small sections which are capable of being automatically cut in or out, step by step, as the conditions require, to maintain a desired voltage at the individual feeder terminals.

These regulators are to have necessary capacity to maintain a pressure of ten volts (200 volts primary) above or below that of the bus-bars. The installation of this apparatus has been delayed by the manufacturer on account of trouble experienced from pitting or burning of the contacts. I am sorry I am not

able to show results of tests on this apparatus and describe its action under practical conditions, as I had intended to do.

Feeder potential regulators are not advisable for use on direct-current systems on account of it being necessary to use batteries, rotary-boosters, or dead resistance in series with the different feeders—any one of these being a most inefficient arrangement.

However, this problem is not so serious, as the entire system can be formed into a network and operated as one unit. Good distribution and regulation can be obtained by the use of a system of interconneeted mains, tied together wherever possible with feeders from high and low bus-bars to determined points, and by use of main storage-batteries.

The automatic generator potential regulator first described as being satisfactory on alternating-current work, was not satis-

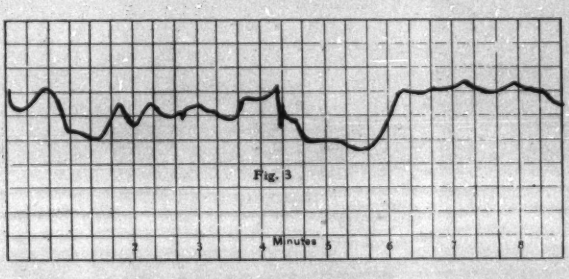

Fig. 3

factory on a direct-current three-wire system. We installed two of these regulators on a pair of 200-kilowatt generators for the purpose of steadying the potential of a three-wire system of about 2,000 kilowatts at peak-load; but they are not capable of doing this, nor even capable of maintaining a potential regulation of less than from 2 to 4 per cent while operating on a separate load. The greatest fault is the tendency to surge or pump (even with a properly adjusted oil-cushion), probably on account of the greater sluggishness or time required to increase or decrease the magnetic density of the solid field-poles of the direct-current generator, as against the laminated field-poles of the alternator. I believe, however, that a later regulator now on the market is capable of maintaining a uniform potential under these conditions, being quicker in its action; as, instead of cutting small steps of resistance, step by step, in or out of the field-circuit, it cuts a large resistance instantaneously in or out of the field-

circuit, and reverses the operation when the potential rises or falls above or below the normal, repeating this performance as often as required. On large generators this regulator operates upon the fields of the exciter instead of on the fields of the main generators.

We have now under consideration the installation of 25-cycle alternating-current generators of large units, to operate synchronous converters for both the street railway and the direct-current lighting systems. This is more complex than the first condition, as the sudden variations of the railway load will have its influence upon the regulation of the generator as well as on the speed of the prime mover. We hope, however, to find a regulator which will maintain an even voltage at the generator terminals under these conditions, and allow us to operate shunt-wound synchronous converters from them and in multiple with our present shunt-wound generators on the direct-current lighting system; also to operate synchronous converters from the same units and in multiple with our present compound-wound direct-current generators on the railway system, by means of series inductance and compound winding on the rotary fields.

A paper presented at the 182d Meeting of the American Institute of Electrical Engineers, New York, December 18, 1903.
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SAFEGUARDS AND REGULATIONS IN OPERATION OF OVERHEAD DISTRIBUTING SYSTEMS.

BY W. C. L. EGLIN.

The distributing system may be considered an integral part of a power-plant and should receive as careful attention as the steam-plant, the hydraulic-plant, or the electrical-plant in the generating station or sub-station. In fact, the distributing system has to meet more severe conditions than any other part of the entire plant, and the safety and reliability of the service depends largely upon the care given to the plans and the selection of material for it.

An overhead distributing system is subject to extreme changes of temperature, extraordinary storms, interference from other lines, interference by building operations, excavations, fires and other casualties, and sometimes a wilful interference by the public (not to overlook the small boy with a stone). All these varying conditions must be considered in the construction of the line. There are two classes of conditions: first, the mechanical or structural; and, secondly, the electrical features.

The first group will include the study of the territory in which the line is to be run: width of streets, kind of buildings, height of buildings; other distributing systems, possibilities of interference with these systems; amount of power to be transmitted, and whether the system consists of a simple power-transmission circuit, or one complicated with distributing mains covering the larger part of the territory occupied by the transmission system.

Also to be considered are the weather conditions: wind-storms, rain-storms, sleet-storms, snow-storms, lightning-storms, and changes in temperature. The method of erecting the conductors

so that they can be properly repaired or additions be made without endangering the lives of the men engaged in this work must be carefully planned. Unless these various points are considered in the construction of the lines, no rules or safeguards for their operation will be of material benefit.

The second group includes the electrical requirements: the conductors, the insulating method of support, and the means provided to take care of any undue disturbances due to lightning or other causes on the line, such as lightning-arresters, fuses, switches, etc.

SPECIFICATIONS FOR MATERIAL TO BE USED.

All of the material entering into the construction of a transmission system should be ordered under specifications which should state clearly the kind of material to be used, and the nature of the tests to which all materials are to be subjected.

The more general requirements are as follows:

Poles.—Poles should be as short as possible to meet the conditions and preferably made of good sound chestnut. Southern cedar or pine poles are sometimes used when chestnut is not obtainable. It may also be necessary to use iron poles under certain conditions. Iron poles are to be avoided, however, principally on account of danger to linemen and also to the short life of the pole, due to rusting. The wooden pole should be roofed at the top to form a right angle, and gained to form a flat of about five inches for attaching the cross-arms.

All poles, upon which are located devices requiring regular inspection, should be provided with steps in order to facilitate this work. Spacing of the poles should be carefully considered and should not exceed from 40 to 45 yards. End- and corner-poles should be braced, and at least every tenth pole throughout the line should be guyed with $\frac{1}{4}$ or $\frac{3}{8}$ inch stranded galvanized wire. Regular inspections, at least yearly, should be made of the condition of the poles; this condition is most readily determined by examination at the base of the pole. When poles are used as junction-poles, that is, when lines are run at right angles and attached to the same pole, special care is necessary. A separate drawing should be made of all such poles, showing the arrangement of the wires—keeping in mind the simplest possible arrangement—as a protection for the men who climb these poles. Switch-boxes, fuses, lightning-arresters or transformers should not be attached to such poles, but on the first pole removed from this junction-pole. Junction-poles can frequently be avoided

by the use of two poles making a Y connection of the line. By this arrangement the connections are very materially simplified.

Cross-arms.—Cross-arms should be spaced at least 24 inches between centres, the top of the first arm being one foot from the top of the pole.

Braces.—Braces should be made of galvanized iron not less than 1¼ x 3/16 inch thick and about 28 inches long.

Pins.—Pins made of locust wood well-boiled in linseed oil are preferable for voltages of 5,000 volts and under; for higher voltages pins should receive special consideration.

Insulators.—The insulator on the pole line fulfils two functions; namely, the mechanical support of the line, and the insulation. As these conditions vary over a wide range, they must be considered for each condition. This is especially so for voltages of 10,000 volts and over. The two materials of which insulators are usually made are glass and porcelain. The glass insulator is more uniform in quality of material than the porcelain, so that for lower voltages glass insulators are recommended. For higher voltages, porcelain insulators are preferred for the following reasons: greater mechanical strength, better insulating qualities, and greater ability to withstand severe weather conditions.

Insulators for high voltages should be made up of a number of insulators cemented together so as to obtain more uniform insulation and to increase the factor of safety from defective manufacture. Before being used, each insulator for high-tension work should be tested at voltages in excess of the operating voltage.

The method of attaching the conductor to the insulator should be carefully considered; first, to see that the wires can be properly fastened to the insulator; secondly, to see that the strain is transmitted without a twisting or bending strain in the insulator. The only strain permitted should be in compression.

The method of distributing the wires on the pole lines depends on the number and character of the various circuits to be installed. For all voltages below 6,000 volts, the wire should be brought out of the station through long porcelain tubes, properly supported; the various circuits being grouped together but well spaced, and preferably being distributed in a single, or not more than a double row of wires. This fan effect allows the circuit to be distributed to the poles without any undue bunchin thus making each circuit easily distinguishable.

The top gain of all poles should be left vacant so that guard-wires can be placed at any point on the line, should they be required. The transmission circuits which are alive twenty-four hours per day should be placed on the top arm; that is, the trunk-lines should occupy the position where there will be the least liability of coming in contact with the other wires or with the men working on the poles. All other circuits should be placed below, series arc-circuits occupying the lower arms, the distributing series circuit being placed on the house side of the lower arms on outer pin occupied by such circuits. The bottom cross-arm should be used for such secondary circuits or low-tension lines as may be required. Space should always be provided for an extra arm on the pole for the erection of a transformer. Protective devices for each circuit may be classified as follows: circuit-breaker, fuses for branch-circuits, and lightning-arresters. Also indicating instruments as follows: voltmeter, ammeter or wattmeter, and ground-detectors.

In the arrangement of the protective devices, it is desirable to locate as many of these as possible in the station or sub-station, for the reason that they are more readily inspected and kept in perfect working order, which insures the fulfilling of their functions when required. All circuits of 200-kw capacity or over should be protected by means of oil circuit-breakers in preference to fuses, on all voltages over 1,000 volts. These circuit-breakers should be attached to both ends of the line, when two or more feeders are used, and connected to the same bus; and there should be no other circuit-breaker or fuses which are automatic in action placed at any other part of the line. Small branch-circuits may be taken care of when necessary by fuse-boxes, placed upon the first pole of the branch-circuit. These fuse-boxes, however, should be avoided whenever possible. This can be accomplished by making a branch-circuit about the same as the main-circuit, depending entirely upon the circuit-breaker in the station to protect both lines. When small branch-circuits are desired, place such fuse-boxes. These preferably should be an enclosed fuse of the cartridge-type mounted on a porcelain base, the whole enclosed in a fireproof and waterproof compartment. This is usually an iron box with a cover and rubber gasket, clamped so as to make it water-tight.

Lightning-Arresters.—Lightning-arresters should be installed at both ends of the line, in the station and sub-station, on each conductor. Special care should be used in their installation, and

provision made that in the event of a breakdown of the lightning-arrester, current may be interrupted by means of a circuit-breaking device.

Series Arc Loop Cut-outs.—These should consist of a mechanically operated switch which closes the circuit at the point of the loop and disconnects the loop from the main line. For the use of constant-potential circuits, there may be either a fuse-box provided with solid catches or fuses depending on the conditions. All of these devices being enclosed in fire-and waterproof cases.

Before considering the actions of the safety-devices, it is necessary: first, to examine the faults which may develop and the functions which the safety-devices are required to fulfil. If the condition of a wire parting is first considered, we have first the liability of the wire coming in contact with some of the other circuits; secondly, its liability to fall into the street, and thirdly, its remaining suspended clear of all circuits and the ground.

The first condition: the effect of coming in contact with other wires, would immediately raise the voltage to the more powerful of the two circuits, so it is evident that the insulation of the other circuit must either be as good or there will be a liability of the insulation breaking down at some point on the weaker circuit. This will first be detected at the station by showing that the load is dropped from this circuit; and it demonstrates that the insulation of all circuits must be the same when placed on the same pole-line, unless means are provided to take off extraordinary high voltages. This can be done by placing spark-gaps, which will relieve the high-tension from any low-tension circuits, or by grounding a point on the lower-tension circuits.

Wires falling on the ground will indicate immediately in the station, on the ground-detector, that there is a ground on that circuit; and instructions should be given that as soon as a ground shows on the circuit and the circuit is not carrying the load, to disconnect it.

The third condition will indicate in the station that the load is dropped and will not show a ground. The circuit should be cut off in this case also, and inspectors sent out to look after the trouble.

Fourthly; if a wire breaks and falls, crossing other wires of the same circuit, this will cause a rush of current on constant-potential circuit and immediately open the circuit-breaker. In the series arc-circuit it will cut out a portion of the circuit which will be indicated on the voltmeter, showing the necessity of

regular voltmeter readings on such circuits.

Interference with Other Wires Falling or Coming in Contact with the Power-Circuits.—If these wires cross the power-circuit and drop loosely on them, the effect will be to short-circuit the power-circuit on constant-potential circuits; the defect develops immediately. The wires either burn off or an arc may be established which will burn off the power-circuit, breaking the wires and the connection. The provision should be as the conditions shown for the breaking of a wire. A single wire may merely come in contact with one wire of a constant-potential circuit and assume the same voltage as that circuit; there will be no way of determining this at either the station or the sub-station, unless that wire was grounded and the ground indicated on the ground-detectors. In the event of this falling wire coming in contact with both sides of the series arc-circuit, a portion of the circuit will be cut out and indicated on the voltmeter at the station. Should it come in contact with only one wire of the circuit, no indication will be made at the station unless the wire be grounded. For this reason inspection should be made and all such wires changed so as to come below the power-circuit and not above it. This also demonstrates the necessity of placing protective-devices on foreign wires which may come in contact with power-circuits.

Lightning-Storms.—The installing of efficient lightning-arresters as specified may protect the apparatus at both the generating station and sub-station, but fail to protect apparatus at intervening points, particularly the transformers. It is possible that lightning may jump from primary to secondary of transformers during a severe storm. This would be indicated by the primary-fuse blowing in the transformer; and after the blowing of the fuse from this cause, tests should be made of the transformer as follows:

It is essential that when a primary-fuse on a transformer is blown through any cause, the secondaries should be disconnected from the transformer, and the latter tested to full-line voltage between the primary and secondary coils, so as to determine that there is no breakdown in the insulation between these coils.

There are two methods by which these tests may be readily made by the linemen without removing the transformer: first, take from the station a 600-watt transformer, connect its primary for the line-voltage and its secondaries for 100 volts, and connect a 50-volt lamp across the latter. Attach one

primary lead of this test-transformer to one secondary wire of the line-transformer, and place one-ampere fuses in the primary cut-outs protecting the line-transformer. Now connect the other primary lead of the test-transformer, first to one and then to the other of the main primary lines. If the 50-volt lamp filament becomes red, the line-transformer is defective, and should be returned to the station. Second method: if impossible to use the first method, proceed as follows: attach a short piece of heavily-insulated rubber wire to one of the secondary wires leading from the transformer. Then place one-ampere

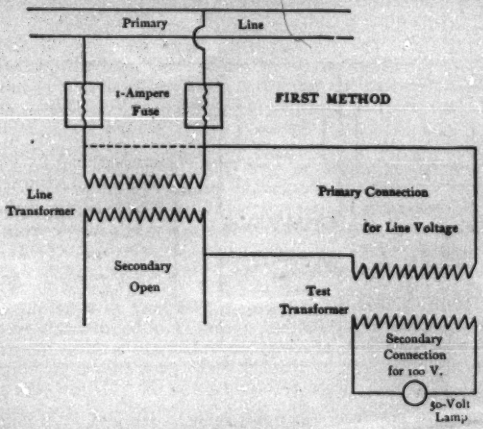

FIG. 1.

fuses in the cut-outs, and connect the specially insulated rubber wire first to one and then the other of the main primary lines. If the fuse blows, or a spark shows when contact is made, the transformer is defective and should be removed from the line.

In the event of lightning-arresters being placed on the pole line, all such lightning-arresters should be inspected after each heavy lightning-storm.

Transformers.—Transformers when supported on the poles should be hung on an extra cross-arm provided for that purpose. The primary leads from the line to the fuse-box and to the transformer should be insulated with rubber-covered braid, for the line voltage. Transformers should not be attached to buildings or in such locations as to be handled by unauthorized

people, and when they are placed in buildings they should be put in a separate fireproof closet or room which is controlled only by the operating plant. As it is now the general practice to use oil-transformers it is unnecessary to consider dry-transformers. Inspection should be made to see that the cases are properly filled with oil. This should be done by an inspection force, and not by the men erecting the transformers.

Inspection.—The greatest safeguard in a transmission line is regular inspection. Lines can with advantage be inspected daily, not only an inspection from the ground, but a regualr monthly inspection of all devices attached to the line when a

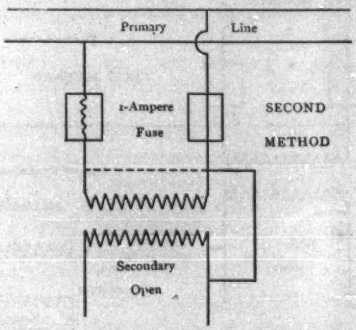

FIG. 2.

continued service is desired.

It may be necessary on some parts of the line to introduce cable. This should be avoided whenever possible for the reason that the conductors are brought close together at this point and static discharge is liable to puncture the insulation; so means should be provided at both ends of the cable to take care of the static. This is best arranged for by a series of gaps of the lightning-arrester type. Standard lightning-arresters can usually be used for this purpose. They should, however, be provided with a small fuse in series with the connection to the line so as to prevent short-circuiting the lines in case of failure of the spark-gaps.

DISCUSSION OF LUKES, BECHTEL, AND EGLIN PAPERS.

H. B. GEAR:—The speaker wishes to emphasize the importance of doing everything possible in the way of providing safeguards on the distributing system to relieve the burden of responsibility now resting upon the central-stations of preserving the continuity of the service. An hour's interruption in a factory employing a number of men may involve great loss to consumer and producer alike.

The development of alternating-current power service in most of our large cities during recent years has served to draw this to the attention of station men very forcibly.

An analysis of reports of line trouble reveals three general classes of accidents which interrupt service; namely, those caused by the blowing of defective or overloaded fuses; those caused by the short circuiting, breaking or grounding of line wires, and those due to trouble in lightning arresters and transformers.

Unnecessary blowing of fuses can be practically eliminated by a systematic method of fusing lines according to the connected load, allowing ample reserve capacity in the fuse and checking up the connected load on all fuses at regular intervals. A set of maps on which the proper size of fuse for each box is marked is of value in this work.

The burning of cross-arms due to the leakage of current from the cases of iron cut-out boxes in wet weather may be reduced to a minimum by mounting these boxes on glass supports. Care should also be used in mounting such boxes on cross-arms not to put them back to back directly opposite each other so that the supporting screws may allow current to pass through the arm and thus burn it. As has been stated by Mr. Eglin, the inability of any form of fuse available for pole-line work successfully to open branches which are fused to carry fifty kilowatts or more makes it advisable to restrict the use of fuses to the branches which are less heavily loaded, depending upon circuit-breakers or station fuses for protection from accidents on feeders or heavily loaded mains. The main branches should be provided with cut-out boxes, however, for use in testing for trouble.

The duration of an interruption of service is usually short, when the occurrence of trouble on feeder or main operates a device located within the station that can be quickly replaced and is not dependent upon the services of a trouble man.

The majority of interruptions are caused by the second class of accidents and may be diminished by first-class line construction combined with a system of regular inspection by which incipient trouble may be discovered. The importance of a regular inspection of all lines at intervals of one to two months has not been too greatly emphasized.

Interruptions due to burnt-out transformers seem to be unavoidable. The use of lightning-arresters located near the larger

transformers is, no doubt, of value in reducing the number of transformers which fail because of lightning, though the entire prevention of this trouble seems to be impossible.

Interruptions due to the burning out of transformers by overloading are very infrequent, it being more often true that the transformer capacity is excessive. Troubles in lightning arresters are undoubtedly diminished by the use of the fuse mentioned by Mr. Eglin, though this would seem to be objectionable from the fact that the fuse might be blown in the early part of a thunderstorm and thus destroy the protection from the remaining discharges of lightning.

The suggestions made by Mr. Lukes, that a standard cross-arm be adopted, should receive general support. A cross-arm similar in dimensions to the one described in Mr. Lukes' paper, except that the distance between the pole-pins is 25 inches, has been in use in Chicago for a number of years with excellent results. Many cross-arms furnished by manufacturers for use on light and power circuits at voltages from 2 000 to 4 000 are likely to cause trouble, owing to the narrow space between the pins, allowing the wires to swing together in case they become a little slack.

Triple-petticoat, glass insulators, having an outside diameter of about 4.5 inches, have been in use in Chicago on 4 000-volt, three-phase circuits for several years with excellent results. There is reason to believe, however, that the deep groove, double petticoat insulator, which is used on standard 2 000-volt work, would serve the purpose equally well as far as insulation is concerned. The advantage of having a distinctive type of insulator on the higher voltage circuits is such, however, that the triple-petticoat insulator is used on these.

Accidents to linemen working on electric light lines may be prevented in part by regulations requiring the men to use rubber gloves in handling live circuits. Much may be done also in arranging apparatus on the pole in such a way that men can work upon without constant danger of injury.

Danger from fire is practically eliminated when primary wires are kept outside of the buildings and all secondaries, whether two- or three-wire, are grounded. The danger from crosses with telephone wires may be reduced to a minimum by carrying all high-voltage wires above the telephone wires, whether in crossing or paralleling them.

Telephone and lighting wires jointly occupy poles on about 200 miles of pole-line in Chicago, the lighting wires being carried above the telephone wires. Several accidents have befallen life and property due to crosses on these lines, but in nearly every case they have been the result of carelessness on the part of telephone line men engaged in stringing wires. Accidents due to lighting wires falling across telephone wires have been almost unknown.

G. T. HANCHETT:—The papers on overhead construction

and distributing systems in suburban districts fail to refer to one of the most prolific causes of accidents and troubles on such lines; namely, the grounding of wires on trees. In a suburban town the preservation of the trees in the street is insisted upon. The wires have to pass through the trees and are secured in various ways; but with the growth of the trees the branches come in contact with the wires and produce serious grounds. Limbs six and eight inches in diameter burn completely in two, the limbs dropping on the street, and wires are burned in two by the resulting arcs. The speaker would be glad to hear of any means which will prevent this trouble.

RALPH D. MERSHON:—The first three papers appeal especially to the operating men, and perhaps some one will answer a question in regard to one of the so-called safeguards used in connection with light and power equipments. Why is weatherproof wire used on primary circuits? After it has been up one or two years it is generally in a very ragged condition, or might as well be so far as its insulating properties are concerned, and as a safeguard, in the matter of protecting life at any rate, it is then worse than useless because it engenders a false confidence.

CALVERT TOWNLEY:—An experiment was made on a railroad in western Pennsylvania some time ago, whereby it was sought to determine how many lightning arresters should be used. A lightning arrester with suitable ground-connection was installed on every pole for several miles, great care being taken to see that the installation was properly made. Tissue paper was then placed in each arrester in such position that it would be punctured if a static discharge passed through that piece of apparatus and after every storm these papers were inspected. It was found that four arresters to each mile of conductor carried off all static disturbances which occurred through numerous and severe thunder storms; indicating that with such a number the tendency for a discharge to escape by any other means than through the arrester was extremely remote.

The fact had been brought to his attention that many operating companies while exercising due diligence in the inspection of the main parts of their system neglected to inspect properly the lightning protection devices, resulting in defective ground connections, undue bends in lightning arrester wiring or other defects which rendered the arrester ineffective. This is a question which is of relative greater importance to the smaller electric light installations than to power-transmission lines, but it has not been given the attention it deserves.

P. M. LINCOLN:—In Mr. Eglin's paper, on page 39, under the head of "Pins," it is said: "The pins should be made of locust wood well-boiled in linseed oil, and are preferable for voltages of 5 000 volts and under." If the treatment recommended is for the purpose of preserving the pins, no criticism is offered. If, however, the treatment is meant for the purpose

of making insulators of the pins, issue must be taken with that statement. The speaker believes thoroughly in treating the insulator as the only insulation of the line and torely entirely on the insulator as the only insulation. It has been noted, particularly on the high-pressure lines, that under certain conditions there is a considerable burning of the pins, particularly if the insulators become coated with dust. There are two ways to remedy that difficulty—one to make the pin a perfect insulator and keep it so, and the other to make it a conductor. You cannot very well make the pin a perfect insulator and keep it so unless you put it in a glass case, and that is a little difficult. It seems that the other method is the logical one to pursue; that is, to make the pin a fairly good conductor, so that the escaping current cannot generate sufficient heat to cause this burning.

M. P. RYDER:—Experience with overhead ines has shown that it is not safe to depend upon the insulation of the wire, whether it is rubber of the best quality, or ordinary weatherproof. Weatherproof insulation is a good protection in dry weather, saving a great deal of trouble that would occur without it. In many cases where wires become crossed, or are thrown together in handling, the weatherproof insulation has prevented short-circuits. (This refers to alternating circuits of 2 500 volts or less.)

Regarding lightning arresters, the speaker has found none that will give complete protection. Lightning does some queer things that cannot be accounted for by any of the accepted theories. Nothing is gained by using a great number of arresters. The greater part of the trouble from lightning occurs at the extreme ends of the circuit. If good arresters are installed at the station, and at the outer ends of the circuits, they will furnish about all the protection necessary.

Why does lightning cause the primary fuses of a transformer to blow without causing any injury to the transformer? Many cases of this kind, both with oil-filled and dry transformers are known. When the fuses are replaced the transformer will go on with its work as though nothing had happened.

GEORGE F. SEVER:—In Mr. Lukes' and Mr. Eglin's papers there is mentioned the possible crossing of telephone and signal with high-tension wires. This is an extremely important point to electrical engineers of municipalities. In the daily papers of December 16th, 1903, there was recorded the fact that at Joliet, Illinois, a feed wire of the Joliet Electric Railway carrying current at 16 000 volts, broke and fell across a Western Union Telegraph Company's wire causing fires in buildings, in some cases, 19 miles distant. It is absolutely essential to eliminate such an occurrence through good engineering practice.

M. P. RYDER:—Regarding the rules of the Underwriters for the building of high-pressure lines: Some of their requirements are not practicable; for instance, the placing of a grounded network

under the high-tension circuit having a conductivity equal to that of the circuit. In a great many cases this would require very heavy construction, so heavy that it would not be practicable to put it on the poles. As a matter of fact, it is very seldom that an electric light or power wire breaks down. A wire of larger size than No. 6 will stand up under sleet, or almost any other storm that occurs in this climate. The proper way to protect low-tension wires is to place them below the high-tension wires.

H. G. STOTT:—Some years ago a Committee of the INSTITUTE met with the Board of Fire Underwriters and a rule was passed making it permissible to ground the neutral at the central point of the transformer, or at one side of the transformer. The grounding of any part of the secondary network, especially the neutral point, is the best form of protection obtainable, because in case of a cross with an electric light wire, carrying perhaps 8 000 volts, the pressure of the wire is immediately reduced to the pressure of the circuit, as the carrying capacity of the secondary network is greatly in excess of the amount of current passing through the average arc-light circuit. Then grounding is also a good protection from lightning, because when lightning strikes the high-pressure line the oil transformer forms one of the best lightning protectors. It is a very common occurrence, as one of the gentlemen remarked, for the primary fuse to blow on a transformer in a lightning storm. This is caused by the current jumping across either between the turns of the transformer and short-circuiting the transformer, or, if the secondary is grounded, jumping through the insulation to that ground. Then automatic apparatus at the power-house ought immediately to cut out that circuit; on replacing the circuit-breaker in the power-house, in nine cases out of ten, the line will be perfectly clear as the oil will have sealed the fault.

It is well to emphasize what has been said in some of the papers to-night that all automatic apparatus should be concentrated in the power-house or substations. It is very well to have some means of breaking up the overhead lines into sections, to have a well-designed oil switch of small dimensions which can be mounted on the poles, so breaking up the line into different sections, so as to render it easy to test and cut out different sections in locating trouble—these things are valuable auxiliaries to engineers who handle overhead service. The question of grounding the neutral is an important one, more especially for the protection of life in possible crosses with higher pressure circuits which must inevitably occur sooner or later in all overhead circuits.

In reply:

W. C. L. EGLIN:—The interference with overhead wires by trees is frequently a source of trouble. There has been a number of methods suggested in connection with the construction of lines through trees. The so-called tree insulator is a porcelain insu-

lator attached to a limb of the tree, or a long wooden insulator attached to the conductor. Neither of these devices is satisfactory on account of: first, the swinging of the limbs of the tree; and secondly, the movement of the conductor, owing to the expansion and contraction of the limb. An insulator attached to a conductor will not have a fixed position, so that any device of this kind must be considered merely temporary. Specially insulated conductors have been used in which a heavy rubber insulation was protected by means of a flat steel armor band wound spirally around the insulation. It was thought that the armor would prevent the chafing of the insulation against the limbs of the trees; and the armor would cut the limbs, instead of the limb wearing away the insulating material. Experience with this form of conductor has not been satisfactory, as the insulation frequently breaks down between the armor and the conductor, and there is no easy method of detecting such a fault.

The author agrees with the criticisms of Mr. Mershon and others that weatherproof insulation is of no value as insulation for the line; and as previously stated, the insulation should be provided for by the insulator, and that pins, cross-arms, and other material are formed by part of the structural features of the line. He has attempted to emphasize that the insulator is the part which should receive attention as far as the degree of insulating is required for the line.

The author differs with the view expressed in the question of gloves for the linemen, and is of the opinion that the use of rubber gloves should be prohibited, for the reason that men depend on gloves and take unnecessary risks, assuming that they are properly protected when using them. There is difficulty in having the gloves returned for inspection, but even with the best care the glove of any value as an insulator should be very much heavier than it is practicable to use. The other objection; although gloves may offer some slight protection to the hands, there are other parts of the body exposed and through which a man may receive a fatal shock. It is better to arrange the various devices that must be handled so that they can be cut out or grounded while being worked upon. An example of this would be a series arc lamp on an iron pole. This lamp might become dangerous owing to the circuit being crossed with some foreign circuit when not in use, and while the trimmers are trimming the lamps. The method of rendering this safe is first to ground the circuit at the station, which is easily done; and further, have a ground connection attached to the iron pole by means of a flexible cable and a hook which can readily be attached to the lamp, thus rendering the trimmer free from any liability of receiving a shock.

The principal reason for placing lightning arresters in the stations is that they can be inspected and kept more frequently in operative condition. Some circuits of about thirty miles in

length have shown continuous discharge, during a lightning storm, at the station. There are undoubtedly locations where it would be advantageous to place lightning arresters on the lines. The location of lightning arresters, however, is a question which has to be studied for each particular locality, and the author does not believe there is any fixed rule for the installation of lightning arresters on distributing systems.

RALPH D. MERSHON:—The speaker is glad to hear the unqualified condemnation of weatherproof wire. In a number of cases, where he has been connected with the installation of power and lighting plants, he has tried to get away from weatherproof wire and put in bare wire. He is also glad to hear what Mr. Eglin says in regard to rubber gloves, as it agrees with his ideas. The speaker has ordinarily been concerned with voltages where rubber gloves are of no value under any conditions, but believes they are ordinarily a source of danger rather than safety. Dependence is put upon them; and although they should be tested from time to time, they are not, and the result is that some one is killed. A man working with his bare hands will take care that the conditions of the work are safe, and such care is better than dependence upon rubber gloves.

H. B. GEAR:—There is one important point regarding the use of weatherproof wire which has not been mentioned. In cases where accidents have occurred to employes or citizens, the question of the insulation of the wire from which the injury was received is the first one to arise. If witnesses can be put on the stand to say that the wire was insulated, the company is placed in a far better position before the jury than it would be were bare wire used.

Weatherproof insulation, while it may not be an insulation of great value as a protection for crossed wires in wet weather, is unquestionably of considerable value in dry weather unitl it becomes so old that the outer braids begin to shred off and become brittle. When it reaches this condition there is but one thing to do and that is to replace the wire.

Weatherproof insulation is of value as a protection to linemen who may be at work on the poles while the circuits are alive, since it protects them from injury which might be caused by momentary contact with 2 000 volt circuits, were weatherproof wire not used.

Weatherproof insulation will remain in fairly safe condition for five years or more.

The speaker agrees with Mr. Ryder that it would be quite impracticable to put up a protecting network which would be required on lines carrying a large amount of energy. There are a great many places in cities where it would be physically impossible to comply with the requirements affecting the distance between poles and buildings, for the reason that where pole lines are run in the street the distance from buildings is necessarily limited. The strict enforcement of some sections of these rules

would prevent the erection and maintenance of high-tension pole lines within the limits of cities.

As to lightning protection, the experiments which have been described this evening show that the average distance between points at which discharges take place is about a quarter of a mile. It has been the practice in Chicago to install arresters at about these intervals, but it has been observed that not infrequently transformers of the old type of first-class manufacture have been burned out by lightning in locations from 300 to 500 feet distant from the lightning arrester.

BRANCH DISCUSSION.

Discussion of Mr. Lyndon's Paper, Meeting at Pittsburg, December 3, 1903.

F. L. Flanders:—Mr. Lyndon says that a battery should not be worked above its one hour rating, and even that only for moderate periods. This rating was established by the largest battery company because its cells cannot be used safely at greater rates. Batteries of the Planté type, made in Germany, do, however, work at much higher rates. The following test was made on a cell of this type, having a capacity of 1 000-ampere-hours at the eight-hour rate: the cell was discharged at 4 000 amperes for 30 seconds; then allowed to rest for 20 seconds; then discharged at from 400 to 500 amperes for five minutes; then allowed to rest for 10 seconds. This completed a cycle, which was immediately repeated. This test was continued day and night for six days of the week, for two and one-half years, and at the conclusion, no depreciation of the cell was to be seen.

In Germany it is customary to work at much higher discharge rates than in the United States, but only for short periods.

The 200-ampere Edison cell is now on the market. For the same power, this cell occupies 17 per cent more space than a lead cell, but for the same weight it gives 40 per cent greater output. The pressure of the Edison cell at discharge is 1.3 volts at first, falls rapidly to 1.25 volts, and after reaching 1.1 volt drops, in about 15 minutes, to 0.7 volts, and five minutes after falls to 0,5 volts; it continues at this for some time and then suddenly goes "down and out." The average voltage of the cell is 1.2. The efficiency of the Edison cell, worked at maximum capacity, is about 35 per cent, but with careful charging and discharging, the efficiency may run as high as 60 per cent.

The principal advantage of the Edison cell claimed by the makers is that it is "fool-proof"; it may be left in any condition of charge without damage; it may be charged and discharged at any rate. As no life tests of the cell have been pub-

lished, the endurance under this treatment cannot be stated. An automobile equipped with these cells is guaranteed to run 70 miles on one charge, but about 20 hours are required to recharge the battery to obtain so great an output ; from 40 to 50 miles is said to be a common run.

H. ETHERIDGE:—The majority of transmission lines in this territory are operated with the differential booster, in which the line current passes through the series field of the booster, as shown in Fig. 15 of Mr. Lyndon's paper.

The average efficiency obtained from our storage-battery is approximately 85 per cent, possibly slightly higher. In some cases where the transmission line has failed, the battery has been placed across the line to supply the service until the line could be repaired and again put into service; in such cases the efficiency probably falls to 60 per cent. We have verified the manufacturer's guarantee that the batteries when operating under normal conditions would exceed 85 per cent efficiency. The deterioration of some of the positive plates of the cells seems however, to be excessive. In some cases, those which have not been in use more than 18 months show strong signs of deterioration. The negative plates seem normal. The positive plates showing signs of deterioration are in cells that were short-circuited by allowing small globules of solder to fall between the plates during process of " burning " the plates.

We get very satisfactory conditions in operating our battery and differential booster. In the operation of batteries we do not find that they require excessive attention. The scaling is of small matter, the renewing of the electrolyte is easily accomplished; specific gravities and temperatures are taken every day and we are thereby enabled to detect a cell that may be short-circuited by scaling. The life of these cells depends very largely upon the way in which they are treated; under average conditions it is safe to allow 10 per cent depreciation for the positive plate. The cell, negative plate, and the electrolyte are of course good for a much longer period.

DISCUSSION OF BECHTEL PAPER AT MINNEAPOLIS, JANUARY 8, 1904.

C. H. CHALMERS:—The ordinary guarantees of regulation of generators, such as six per cent increase on pressure of non-inductive and 19 per cent on load with 80 per cent power-factor, mean practically no regulation. A proper specification for pressure regulation should include a pressure regulator guaranteed to keep the pressure within one per cent of normal for speed variations of five per cent from normal, either way, for a variation of power-factor from unity to 75 per cent, for variations of load from zero to 50 per cent overload, and for changes of temperature of the generator from that of the room to 55° Centigrade above the room temperature; and this regula-

tion should be obtained when any or all of these causes of variation exist simultaneously. There are four principal sources causing variations of pressure, as follows: variation in speed, in the load, in the power-factor of the load, and in the changes of temperature. A pressure regulator external to the generator actuated by variation in pressure alone is a perfect remedy for variations due to any or all of these sources, and moreover permits the use of the very simplest form of generator, eliminating series coils and all apparatus for compensating pressure changes.

GEORGE D. SHEPARDSON:—Automatic regulators ordinarily cause as much trouble as they are supposed to eliminate; they have usually been untrustworthy, and it is as necessary to have an attendant to watch the regulator as it would be to watch the pressure changes themselves; there is practically no saving in attendance. Moreover, as long as central stations charge for energy and not for light, there is little direct incentive to them to give the best regulation, since their income is not increased thereby. The interest of the central station man is rather to use all low efficiency lamps and the consequent sale of a greater amount of energy for a given amount of light.

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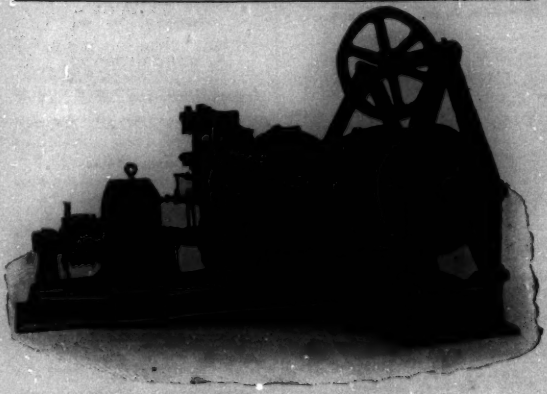

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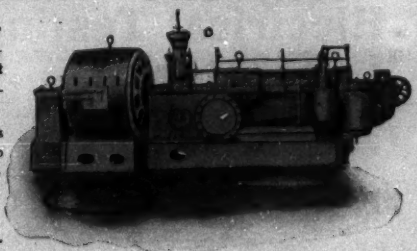

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